"paragraph 0002". There exists a bipolar static induction transistor comprising elements of a bipolar static induction transistor -- a gate, a source and a channel -- on one of the sides of the substrate, and elements of a onejunction transistor -- an emitter and a base (drain) -- on the other [3]. This transistor has high current density and can switch high power. The drawback of the transistor is that it cannot operate on circuits of alternating voltage (to be more precise, it can (only) be closed by (supplying) applying only one of polarities of the drain-source voltage).

"paragraph 0003". There exists a bipolar transistor, which has structure actually comprising two bipolar transistors and which can operate(s) in alternating-voltage circuit [4]. The drawback of the transistor is that it cannot has high technical characteristics. Its breakdown voltage, current density and switch power are low.

"between paragraph 0003 and 0004". There exists a vertical bidirectional MOS-type semiconductor device, that facilitates controlling a DC current and an AC current at a relatively low on-voltage[5]. The bidirectional MOS-type semiconductor device includes a first n-channel IGBT and a second n-channel IGBT. The first n-channel IGBT is formed of n.sup.+-type source 102, p-type base 103, an n.sup.--type substrate 101 and p-type anode 104. The second n-channel IGBT is formed of n.sup.+-type source 105, p-type base 104, an n.sup.-type substrate 101 and p-type anode 103. The operation of the second n-channel IGBT is the inversion of the operation of the first n-channel IGBT. The first n-channel IGBT makes a current flow from a first terminal 106 to a second terminal 107. The second n-channel IGBT makes a current flow from second terminal 107 to first terminal 106. Drawbacks of the device are that current density of the device is insufficient; it is desiable to decrease on-voltage.

summary of the invention

"paragraph 0004".The advantage of the offered transistor (offered) is that it can operate in both constant-voltage circuits and alternating-voltage circuits for example (220) 120 V and (over) more (breakdown voltage is as a rule to 1--2kV), (which means that it can be both closed and open with any voltage polarity) and have a high technical characteristics at that: a high current density, a high switch power and a very low on-voltage. Besides, the thick channel connected to a separate electrode provides increasing maximum (without latch) current of the transistor and simplification of many circuits, which use the transistor.

"paragraph 0005". This result is achieved by disposing elements of the bipolar static induction transistors: (a) two gates, (a) four sources, (and a) channels (as well as) and six electrodes (and isolation) on (each of) either side(s) of a lightly doped n-type silicon monocrystal substrate, and besides one of said (the) channels of the multielemental structures (on each of the sides of the substrate) is thicker than the other channels on either side of said (the) substrate and said thick channels are connected to (a) the separate electrodes on either side of said substrate.

"paragraph 0006" is canceled.

"paragraph 0007".This result is achieved by disposing an epitaxial layers (on each of the sides of the lightly doped substrate) of the same type of conductivity with the impurity concentration about 10.sup.17 cm.sup-3 on either side of said substrate; (in which elements of the bipolar static induction transistor:) (a) said gates, (a) said sources and (a) said channels (-- as well as electrodes and the isolation) are disposed in said epitaxil layers.

"paragraph 0008. The offered transistors (offered) can be applied for production, transfer and use of electric energy within a very broad range of power: from the control of electrical

soldering to the control of most powerful turbogenerators and thermonuclear stations. They are effective for designing electronic transformators, power supply units, and "flexible transfers of alternating current". In the latter case transistors can be connected in series, which will allow to easily create high voltage system with operating voltage 10.sup.6 V and (over) more with a control with light signals. These transistors can be most widely used in the devices aimed at defending people from electric shock. They can also be used in systems with the unipolar power supply transmitting energy in both directions -- both from a source to a load (resonator) and from (a) the load to (a) the source. It will make it possible to increase circuit efficiency with the voltage drop between a drain and source of the open transistor as a rule not exceeding 0.5 V and, if necessary, it can be highly close to zero.

"paragraph 0009". For manufacturing offered transistors one uses a lightly doped n-type substrate of monocristalline silicon with long life time. The structure of the offered transistor (offered) is symmetric which means that on either (each of the) side(s) of the (lightly doped n-type) substrate with the impurity concentration being 10.sup.14 cm.sup.-3 there are areas of a p.sup.+-gate, a n.sup.+-sources, (and) an ordinary (n-)channel and the thick channel as well as the electrodes of gate and sources (drains). Owing to the structure symmetry, the output voltage-current characteristics of the transistor are symmetric and are in the first and the third quadrants. Because of this, the source and drain of the transistor can change places and the transistor can operate in alternating voltage circuits of supply pressure of (220) 120 V and (over) more which simplifies (designing of) many circuits and besides the transistor can be applied in the circuits which cannot be produced with any other types of transistors.

"between paragraph 0009 and 0010". There are different operating duties of transistor on-condition:

1.A hole concentration approximately is the same in the whole lightly doped area. The diffusion current is negligible. The gate disposed near the drain of the transistor emits holes into the channel and lightly doped area. The holes drift to the source of the transistor and are extracted by the gate disposed near the source. The electrons drift to meet holes -- from the source to the drain of the transistor. The electron concentration equals approximately hole concetration. The electron current is 3 times bigger, than the hole current, owing to the electron mobility is 3 times bigger. The features of operation duty -- a low current amplification factor, high speed response.

2.A hole concentration near the source of the transistor is essentially bigger than the one near the drain (trapezioidal distribution). Owing to this, a hole current consists of two parts: a hole diffusion, directed from the source to the drain and a hole drift, directed from the drain to the source.The hole current can be for example equal to zero (zero approximation).An electron concentration approximately equals the hole concentration.An electron diffusion current and the electron drift current flow in the same direction -- from the drain to the source.So almost all the current is transferred by elecrons on the way of which there are almost no potential barriers and besides on the greatest part of the way the concentration of impurity is small and, correspondingly, the dispersal of carriers on impurities is small and the mobility of carriers is high as well as the concentration of holes near the drain is high. As a result, the transistor has an unusially low resistance on condition and this permits the high density current to flow at a low potential difference between the drain and the source. The small hole current is formed at the expense of recombination holes and electrons in the source and the smaller one is formed at the expense of recombination in the drain.Big hole currents flow through gates at the switching over of the transistor only: at an opening of the transistor by emission of holes from gates into lightly doped area and accumulation of holes; at a closing one by discharge of holes (extraction).

"paragraph 0010". Though the structure of the transistor is symmetric the operating duty of the channel that is near the drain of the transistor essentially differs from the operating duty of the channel that is near its source. The electrical field reduces the concentration of holes in the former and increases their concentration in the latter. Owing to this, the hole concentration along an axis perpendicular to surface is trapezioidal in zero approximation. It puts certain restrictions both on the design parameters of BSIT and on designing of circuits in which these transistors are applied. <u>Introduced in the structure the thick channel provides increasing of operating current (without latch). A threshold voltage of the thick channel is lower than that of the ordinary channel</u>. Algorithm of control of the <u>offered</u> transistor (offered) under typical circumstances is more complicated than that of the transistor described above ([1]) [3]. <u>Let potentials of the gates are equal to potentials of the source and drain accordingly. The electrons flowing to the drain electrode can cause emission of the holes from the gate, disposed near the drain. The holes flow to the gate, disposed near the source. Part of the holes flow into the channel and causes the flow of the electrons to the drain. So, there is a positive feedback in the device. Device is latched. On-voltage of the latched device is more than on-voltage of the open transistor. To preserve the feedback it is necessary to provide so that electrons might flow to the drain free. It depends both on a control circuit and on the construction of the transistor. The part of the control circuit is represented on fig.10 of the application. Electrons might flow to the drain through open transistor 113 or 123. (In the simplest variant the thick channel drain electrode has been connected to the ordinary channel drain electrode with a conductor.) The construction of the transistor provides the way for electrons to the drain through the thick channel while transistor is closed or is being switched off. The potential of the thick channel drain electrode has to be positive or zero or little negative relative to the potential of the drain electrode of ordinary channel. The high drain voltage extracts electrons from the thick channel which is disposed near the source. The potential of the thick channel source electrode has to be positive so that the thick channel is closed.(It is allowed that the potential of the thick channel source electrode might equal zero, if the threshold voltages equal approximately 0.2 volt.It is desirable that the threshold voltage of the channel, which is disposed near the source is higher than 0.2 volt, the threshold voltage of the channel, which is disposed near the drain is lower than 0.2 volt).</u>
(To achieve optimum characteristics three rather than two different levels <u>of</u> voltages should be applied to the transistor gates. One of the voltages to the gate is about zero relatively to the nearby source, with the transistor channel closed, while the voltage applied to the gate near the drain should be about 0.4 V with the channel slightly open and the gate emit(ting) very low hole current to the lightly doped area).
When changing polarity of the <u>applied</u> voltage (applied), the source and (the) drain change places, and (the voltages to the gate<u>s</u>) <u>the potentials of the thick channel electrodes</u> should be changed acco<u>r</u>dingly so as the transistor is to remain closed. In this case the transistor can maintain voltages up to several kilovolt depending on parameters of the lightly doped area. Another voltage on the gates is about 0.8 V relatively of the (sourse) <u>source</u> and (the) drain which are nearby. It provides the opening of the channel<u>s</u> and hole emission <u>in</u>to <u>the channels and</u> the lightly doped area. The emission of holes to the lightly doped area is followed by electrons from the transistor source which makes the hole concentration and electron concentration practically the same in zero approximation and may reach the magnitude of 10.sup.17÷10.sup.18 cm.sup.-3; resistance of the transistor drops sharply due to conductivity modulation and the voltage between the drain and (the) source of the transistor <u>as a rule</u> does not exceed 0.5 V at current density≈1000 a cm.sup.-2. (The level of 0.4 V can be substituted by) <u>There is a</u> smoothly lowering voltage on the gate which is near the source of the transistor during the switching of the transistor from on-condition to off-condition, <u>owing to extraction. To decrease the loss of switching off the voltage on the gate which is near the drain of the transistor</u>

should be decreased smoothly during the first part of time of switching off (approximately 1 us).

"paragraph 0011". To increase operating current of the (have completly controllable) transistor (without latch), the offered BSITs (offered) should have the channel with a low resistance. To this end, thickness of the channel should be small and the impurity concentration near the gate should be high enough so that the electronic current flowing near the gate could not cause a large voltage drop which, in turn, could lead to emission of holes. To meet these requirements, it is desirable to grow an epitaxial layer with donor impurity concentration being about 10.sup.17 cm.sup.-3 on the surface of the lightly doped substrate having the donor impurity concentration about 10.sup.14 cm.sup.-3, and to have an equipment with higher resolution than is generally used for manufacturing other BSITs. On the surface of a monocristalline silicon a layer of a polysilicon may be disposed that would help to form the elements of the transistor -- the gate, the source, the channel and the electrodes. The other variant -- implantation of both donor and acceptor in the gate and double drive-in diffusion to provide thin layer donor impurity near the gate.

"between paragraph 0011 and 0012". A solitary pulse current density can be several times bigger, tending to 10000 a cm.sup.-2. Auger recombination restricts the carrier density. In this case the hole concentration is approximately the same in the whole lightly doped area. The influence of diffusion currents is negligible. The offered transistors, as the transistor [3], can control power greater than any other types of transistors all over the world.

"paragraph 0012". There are several different ways of using the thick channel. One of them is reported below. The control signals on the gates of the transistor should depend both on a polarity of the supply voltage (as a rule, it is alternating voltage with the frequency 50-60 Hz) and on the voltage applied (supplied) at the moment to the transistor; (to do so, it is desirable to introduce to the transistor structure) two normally-on channels (transistors) with small (saturation) current have been introduced to help to (fix) determine the value and the polarity of the voltage on the transistor at that moment. Signals from these channels (transistors) are transmitted to the control circuit which produces control signals to the gates. Besides, potentials and currents applied to electrodes of normally-on channels with control circuit are changing the operating duty of the transistor and the transistor-thyristor themselves. As a rule, thick channel source electrode occupies not more than 20% of square of ordinary channel source electrode.

"paragraph 0013". It is desirable to dispose driver transistors (should be disposed on other substrates "bonded" with) on the chip above the main one. Most suitable transistors for the driver are low-voltage bipolar static induction transistors. Due to a (their) small size, (their) they have sufficiently low resistance (is low enough when) on-condition, (they also have) high gain and high speed response to control a power transistor. (Such transistors) Part of the control circuit on either side of the chip can be controlled by light signals with the help of photodiodes or by wireless.

"paragraph 0014". In a zero approximation, the offered transistor (offered) does multiplication of voltages applied to the transistor gates and drains and can be considered as double-band modulator and can be used, for example, to control polarity of rectified voltage.

"paragraph 0015". Apart from the main purpose of application, that is using the (transistor) device as a completely controlable power bidirectional key, (similar structure) the device can be used as transistor-thyristor (for other purposes); to achieve these purposes, both the control of emission and of extraction of holes into lightly doped area are used, as well as current feedback for the control of emission (for example, latch when manufacturing a switchboard). The current feedback provides the hole emission from the gate, which is near the

<u>drain of the device, if the resistance of the channel is high and the control circuit provides it.</u>

"paragraph 0016". The transistor with an offered combination of features is unknown, therefore the offered transistor <u>corresponds</u> (is corresponding) to a criterion "novelty".

"paragraph 0017". The offered combination of features does not obviously follow from the engineering level, therefore the transistor <u>corresponds</u> (is corresponding) to a criterion "invention level".

"paragraph 0018". The purpose of the invention and the means and methods of its realization are indicated in the application documents, its purpose being realizable,--which means there is "industrial applicability".

<u>brief description of the drawings</u>

"paragraph 0019". Inventions is explained with (three) <u>seven</u> drawings.

"between paragraph 0019 and paragraph 0020". <u>Fig 1,2 represent a bipolar static induction transistor structure (prior art)</u>.

"paragraph 0020" is canceled.

"between paragraph 0020 and paragraph 0021". <u>Fig.4 represents a power normally-off transistor-thyristor structure with two lowpower normally-on channels.</u>

<u>Fig.6 represents a power normally-off transistor structure with two lowpower normally-on channels disposed in epitaxial layers.</u>

"paragraph 0021" is canceled.

"paragraph 0022". Fig.(3) <u>8</u> represents a symbolic image offered of the power normally-off transistor with two lowpower normally-on <u>channels</u> (transistors).

"between paragraph 0022 and paragraph 0023". <u>Fig.9 represents bidirectional semiconductor device structure (prior art).</u>

<u>Fig.10 represents offered transistor with a part of the control circuit (one from several variants;for illustration only).</u>

<u>detail descreption of the preferred embodiment</u>

"between paragraph 0022 and paragraph 0023". <u>Bipolar static induction transistor fig.1 comprises substrate 1, drain electrode 2, epitaxial layer 3, gate 4, gate electrode 5, source 6, channel 7, source electrode (n+-type polysilicon) 8, source contact 9.</u>

<u>Bipolar static induction transistor fig.2 comprises substrate 10, drain electrode 11, epitaxial layer 13, gate 14, gate electrode 15, source 16, channel 17, source electrode (n+-type polysilicon) 18, source contact 19, isolation 20.</u>

"paragraph 0023" is canceled.

"between paragraph 0023 and 0024". <u>Bipolar static induction transistor-thyristor fig.4 comprises lightly doped n-type substrate 28, gates 29, gate electrodes 30, thick channels 31,</u>

thick channel source electrodes (n.sup.+-type polysilicon) 32, thick channel sources 70, ordinary channel sources 33, ordinary channels 34, ordinary channel source electrodes (n.sup.+-type polysilicon) 35, ordinary channel source contacts 36, thick channel source contacts 37.

Bipolar static induction transistor fig.6 comprises lightly doped n-type substrate 47, epitaxial layers 48, gates 49, gate electrodes 50, thick channels 51, thick channel sources 69, thick channel source electrodes (n.sup.+-type polysilicon) 52, thick channel source contacts 53, ordinary channels 54, ordinary channel sources 55, ordinary channel source electrodes (n.sup.+-type polysilicon) 56, ordinary channel source contacts 57, isolation 58.

"paragraph 0024" is canceled.

"paragraph 0025". Symbolic image of power normally-off transistor with two lowpower normally-on channels (transistors) comprises gates (12, 13) 63,64; (drains ()sources ()) of lowpower channels (transistors) (14,17) 65,68; (drains ()sources ()) of a power transistor (15,16) 66,67.

"between paragraph 0025 and 0026". Bidirectional semiconductor device fig.9 comprises substrate 101, n.sup.+-type source 102, p-type base (anode) 103, p-type anode (base) 104, n.sup.+-type source 105, terminals 106,107.

Fig.10 comprises offered transistor 110, hole emission key 111, hole dischage (extraction) key 112, electron dischage key 113, amplifier with nonlinear feedback (polarity fixture)114,115,113; hole emission key 121, hole dischage (extraction) key 122, electron dischage key 123, amplifier with nonlinear feedback (polarity fixture) 124,125,123; (transistors 111,112,113,121,122,123 -- lowvoltage bipolar static induction transistors).

"paragraph 0026". The offered transistor (offered) can be named "symmetric channel (tetrod) gecsod" or "bidirectional bipolar static induction transistor"-- "BBSIT".

"paragraph 0027" is canceled.

"paragraph 0028". Improvement of characteristics of the transistor can be achieved by cooling with help (using it under the temperature) of the liquid nitrogen.

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P.S.Чтобы добиться увеличения рабочего напряжения прибора, можно, например, обработать край чипа известными методами, включая, например, травление.